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Development and evaluation of a learning management system for dental radiographic interpretation practice

영상치의학 판독 교육을 위한 학습 관리 시스템의 개발 및 평가

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치의과학과 영상치의학 전공

장 희 진

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이 논문을 치의학박사학위논문으로 제출함

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Abstract

Development and evaluation of a learning management system for dental radiographic interpretation practice

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Purpose: Moodle (Modular Object-Oriented Dynamic Learning Environment) is a well-known and verified open-source learning management system(LMS) software. This study aimed to develop and evaluate an LMS for dental radiographic interpretation practice using Moodle.

Materials and Methods: The last stable version of Moodle was installed on a server, and customized for dental radiology education, named e-OMFR. After the installation process, a new course was created and set according to the learning purpose and teaching situation. The e-OMFR was constructed with four parts: glossary, wiki, forum, and quiz. Among the functions of e-OMFR, the quiz function was used for radiographic interpretation practice. Third-year undergraduate students were divided into two groups. The experimental group utilized e-OMFR for dental radiographic interpretation practice. The control group completed the

radiology practice session as usual, whereas for the experimental group, 10% of the interpretation practice time was replaced by online practice for dental caries diagnosis on panoramic radiographs using e-OMFR. The students in the experimental group practiced diagnosing caries in more than 100 panoramic radiographs through online quizzes. The effectiveness of e-OMFR was evaluated by comparing the final examination scores of the two groups. The e-OMFR was surveyed by administering a questionnaire to students in the experimental group.

Results: The process of installing and customizing Moodle proved to be feasible and cost-effective. Moodle was suitable for developing an LMS for dental radiographic interpretation practice. The students in the experimental group achieved higher scores in their final examination than those in the control group on the 10 questions related to interpreting dental caries on panoramic radiographs ($p<0.05$). On the other hand, no significant difference was detected between the groups on the other 50 questions and on previous examinations. Among the members of the experimental group, 54% answered that they found the system inconvenient. The main reason for the inconvenience was that there was no image enlargement or control function. Nevertheless, 27% indicated that the online quizzes were helpful for dental caries interpretation practice.

Conclusion: The incorporation of e-OMFR in current teaching was shown to improve student performance. The e-OMFR would be practically applied to radiographic interpretation practice if the function is improved. The e-OMFR could be extended to continuing education for dentists.

Key words: Dental Education, Computer-Assisted Instruction, Dental Radiology

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I. Background

The development of information technology has changed traditional perspectives on the educational environment and pedagogy. The role of the instructor has changed from that of a knowledge provider to a facilitator who aids learning, and the learner is becoming a self-driven participant who locates, transforms, and creates information him- or herself instead of being a passive acquirer of information.

According to Prensky,[1,2] students today, referred to as digital natives, use technology throughout their lives and can thus be differentiated from previous generations of students in their ability to apply information technology and communication skills smoothly. The methodology and contents of education should be changed to suit these learners' characteristics.

As the higher education paradigm shifts from teacher-centered to learner-centered classrooms, university-level education should consider the following factors. First, education should be conducted using various teaching methods that consider individual differences. Classes presented to everyone in the same way cause students in the younger generation to lose interest. Students today prefer diversity over uniformity. They do not follow customs or established, authoritative behavior patterns but, rather, pursue self-assertiveness and self-esteem. Therefore, they should be provided with education that develops their creativity by enabling them to create and enhance their own unique personality, and they should be given the opportunity to produce and utilize useful intellectual value.

Second, learning should take place through digital technology. Students in the so-called millennial generation are highly digital, using the Internet and mobile devices as their primary means of communication and information sharing, and they

are accustomed to interacting collaboratively both online and offline. It is essential to actively use digital media such as the Internet so that students can learn in a self-directed manner, not limited to the standard place and time for learning. Maximizing the learning capacity of the digital generation involves equipping them to select relevant information from the massive amount available, teaching them advanced knowledge closely connected to the real world, and enhancing student participation and interactive education in the classroom.

Learning is a set of processes that entail the acquisition, maintenance, and creation of information. To master these processes in a contemporary context, e-learning may become mandatory. Therefore, it is necessary to discuss the possibilities and effectiveness of e-learning in dental radiology education.

(1) E-learning in medical education

Modern medical education deliver an enormous amount of knowledge and information to learners, and the pace of change is so rapid that it is difficult to deal adequately with all the required knowledge and skills through traditional lecture classes alone. To adapt to environmental changes in medical education, e-learning is spreading across the world.[3-12] E-learning allows much more flexible learning for medical students, who have to contend with busy schedules; furthermore, the varied multimedia resources and abundant visual materials that can be provided through this mode are helpful for their education. Therefore, e-learning is an important educational tool in medical education today, enabling learning using information communication and electronic media without time and space constraints.

In the United States, the quality and efficiency of the current medical school education model is under discussion,[13] and several attempts to change it are underway. Perceived shortcomings of the current system include inefficiency,

inflexibility, and lack of learner-centeredness. A new alternative is student-centered lectures, in which students study a case in advance and then discuss it in class using an audience response system. In addition, blended learning, which combines traditional educational methods and online classes, has been proven effective in radiology education during clinical internships.

(2) E-learning in dental education

The use of e-learning has increased rapidly in dental education over the past decade,[14-19] as reflected by research in the field. Studies on the development, implementation, and evaluation of online and blended courses have been conducted in many disciplines within the dental curriculum, such as undergraduate and postgraduate orthodontics, anatomy, oral pathology, fixed and removable prosthodontics, radiological anatomy, restorative dentistry, dental terminology, and health informatics. Dental school students have generally expressed positive views regarding the use or potential use of e-learning due to its flexibility, availability, and convenience that is lacking in face-to-face teaching.

Boberick[20] reported on the development and implementation of a web-enhanced, interactive preclinical manual for a course on restorative techniques, finding that it successfully delivered information beyond the capabilities of the textual format. According to Handal et al.,[21] undergraduate students at dental schools reported positive attitudes toward e-learning; however, they seemed hesitant about more active learning behaviors such as online forum discussions. Aly et al.[22] compared the effectiveness of an interactive multimedia courseware package to that of standard lectures in orthodontics; the interactive multimedia program was almost as effective as the standard lecture approach for undergraduate training. Mattheos et al.[23] reviewed the potential of information technology in dental education to

enable distance learning because educational materials can be shared without time and space restrictions. As basic science subjects often suffer from a shortage of faculty, it can be advantageous to share lecture materials between schools. In addition, student-centered education and an individualized curriculum and evaluation are possible.

(3) E-learning in dental radiology education

E-learning in dental radiology is still relatively rare. Ramesh and Ganguly[24] introduced the Learning Catalytics program for interactive learning in oral and maxillofacial radiology, finding that it improved bidirectional communication between learners. Wu et al.[25,26] demonstrated that a web-based training method was valuable in dental radiology education and could supplement current educational practices without increasing the teaching load. Moreover, it could further reinforce and improve students' ability to read dental radiographs. Kavadella et al.[27] developed and implemented a blended course on undergraduate oral radiology; in their comparative study, the students in the blended group performed better than those in the control group. Within the blended group, female students performed better than males.

With traditional education methods, basic knowledge is delivered through textbooks and lectures. However, high-quality images and videos can provide students with basic knowledge of radiology principles more effectively.[28] Moreover, it is possible to reduce individual differences in learning ability by offering students online lessons before or after lecture classes. Online materials can be reviewed repeatedly, at any time or place. Basic education on diagnosing dental radiographs should be practical and requires repeated experience.[29] Web-based, high-quality digital resources can lessen the teaching burden on faculty and allow students to

develop in a self-paced, student-directed learning environment. Video editing software and Internet video streaming technologies enable the creation and use of high-quality video for dental education. As it can be used anytime, anywhere, and repeatedly, web-based learning can contribute significantly to improving one's clinical abilities in diagnosing dental radiographs.

Dental radiographic interpretation practice is heavily dependent on the examination of visual images; hence, a database of case-based dental radiographs is an important tool in radiographic interpretation practice. Digital radiographs are now more common than hardcopy films, making it easier to create a database of educational radiographs than it was before. Furthermore, the development of modern information and communication technologies has enhanced the scalability of data in a database so that more educators can use this resource.

Two important issues in contemporary education are blended learning and flipped learning. Blended learning is a combination of two or more learning methods; online learning and face-to-face learning often refer to mixed learning. Flipped learning, reversal learning, and backward classrooms are a form of mixed learning that uses information technology to maximize learning in class. This is a teaching and learning method that allows more time for students to interact. In a common implementation of flipped learning, the teacher prepares the class images and materials in a form for the students to prepare before class time. Then, in the classroom, the teacher can spend more time interacting with students or doing more intensive learning activities than teaching the content. Using Likert-scale data analysis, Varthis and Anderson[30] reported that students had positive perceptions of a blended learning experience in dental education. Park and Howell[31] reported that the use of quizzes and peer assessments before and after class contributed to increased student participation in class and was an important

motivator to help students demonstrate accountability. Student feedback from the post-experience survey was generally positive for the collaborative and interactive aspects of this form of mixed learning. The results showed that the e-learning tool was appreciated by the students and suggest that learning objective tests can be successfully implemented in blended learning. Reissmann et al.[32] demonstrated a Model of Blended Learning in a Preclinical Course in Prosthetic Dentistry. They showed that the students appreciated the e-learning tool and likewise suggest that learning objective tests can be implemented successfully in blended learning.

El Tantawi et al.[33] reported that it was possible for dental schools with large class sizes and limited resources to use e-assessments as a means of managing student progress. Information technology increased the efficiency of the assessment process, decreased teaching workloads, and provided students with timely feedback on their performance. According to a study by Seluakumaran et al.,[5] a significant correlation existed between students' scores on online quizzes and their final exam scores, further substantiating the value of e-assessment. However, instructors should consider security issues and patient privacy.

II. Introduction

A learning management system (LMS) is a software application for the administration, documentation, tracking, reporting, and delivery of e-learning courses.[34-38] In other words, it is software that automates a series of administrative tasks related to education. It helps to manage learners' logins, record learning activities and learning outcomes, and provide reports on these. In addition, it is a web program that provides various functions for content production, offline education management, lecturer management, learner collaboration, and learner ability management.

To build such an LMS, schools and academic departments typically must purchase commercial software at great expense, develop it in-house, or outsource it. However, Moodle is an open-source software whose source code is published publicly so that anyone can view or use it free of charge. Along with Moodle, currently popular open-source LMSs include CourseSites by Blackboard, Sakai, Latitude Learning, Dokeos, Schoology, ILIAS, ATutor, Canvas, ELMSLN, and Google Classroom. Moodle is most convenient in terms of ease of use. It can be installed on any computer and run on most operating systems. Depending on the needs of the teacher and students, the modules can be relocated or the learning environment can be changed efficiently for the users. Therefore, Moodle has been used effectively in many areas, including medical education. Moodle is an important open-source option among LMS platforms and is supported by an extensive technical infrastructure with many plugins and options allowing customization.[5,34,35,39,40] Moreover, considerable online documentation is available to help users with support issues or questions (see Moodle's home page, http://moodle.org/).

Moodle has grown from an idea in a doctoral dissertation at Curtin University of Technology to become a leading, publicly available LMS. It is based on social constructivist learning theory and contains a modular structure that maximizes user convenience and flexibility. According to the official Moodle website, the system has been used to develop 84,000 learning sites in 237 countries, making it the world's most widespread LMS. Several universities have applied Moodle in Korea. System upgrades and technical improvements continue to be made. The community of Moodle users is characterized by various learning activities such as wikis and forums for mutual learning among students.

The main problems with the traditional teaching method are as follows: individualized education cannot be achieved due to lack of consideration of individual differences; the reliance on textbooks makes it impossible to learn through image-based data related to actual clinical practice; and there is not enough time for practice in diagnosis of dental radiographs. In contrast, Moodle enables the posting of various types of learning resources such as voice files, video files, and images. It can also enhance learners' motivation by complementing text-oriented materials.

The use of an LMS can be helpful in connection with the blended learning and flipped learning that have become common in education. First, it can be used for blended learning that integrates online and offline instruction.[27] This requires a scientific approach to maximize the benefits of both online and offline environments in order to increase the effectiveness, efficiency, and motivational appeal of learning, instead of simply adding online elements to classroom instruction. Above all, a learner-centered approach that enhances the accessibility, convenience, and flexibility of learning is important. The aim of using an LMS was to guide instructors to build an effective blended learning environment that uses online and

offline material complementarily. Improvements in learning effectiveness and increased communication between instructors and students are among the benefits expected from blended learning.

Second, an LMS can be used for flipped learning—a newly emerging teaching and learning method that has been influenced by educational informatization. In flipped learning, students complete their preliminary learning about a topic outside class (perhaps by watching a video) and then discuss with the instructor during class, rather than listening to a lecture. This method, which is now widely used in graduate-level classes, is not entirely new. In some respects, it is indistinguishable from blended learning.[13] Flipped learning has attracted attention in recent years because it relates to the dramatic expansion in the data sources available to students to guide their prior learning. Readily available open-source materials have received wide use because Internet connectivity has become ubiquitous and philosophies and tools related to informatization, such as collective intelligence and Wikipedia, have been introduced into education. In other words, the availability of excellent online learning materials based on participation, openness, and a spirit of sharing, which have had a powerful impact on educational informatization, is a driving force behind flipped learning.

Khan Academy has demonstrated how these methodologies are implemented in the field.[41-44] Students learn information from online videos before coming to class. They can learn in the way that is best for them, anytime and anywhere, at their own pace. If they do not understand well, they can repeat the lesson, and can use the discussion board or bulletin board provided on the site to ask or answer questions and interact with other learners. In the classroom, students then engage in supplementary learning as needed to achieve the learning goals set by the teacher, based on their level of prior learning. If they have already achieved the

learning goals through prior study or experience, they can proceed to in-depth learning. This is not a traditional lecture method but a team-based method. Students are grouped into those needing supplementary learning and those ready for deeper learning through a simple diagnostic evaluation. In this way, individualized learning can be conducted according to each student's level of knowledge. The teacher's role in this process is more diverse and important than in the traditional lecture method. Teachers should provide high-quality materials so that students can learn effectively and should perform various roles, such as instructor, manager, and facilitator, so that students can learn in an individualized way according to their prior learning level.

This type of learning is suitable for dental education.[31] First, owing to the large amount of knowledge that must be acquired, students have traditionally had to learn passively in the classroom, but now, they can learn actively, supplementing and deepening their learning. They can find lecture materials on their own, complete preliminary learning before class, examine their learning level during class, and take advantage of ways to improve. Second, students who may feel rushed or overwhelmed by the material delivered in a relative short class period can use their time more efficiently and conduct self-directed learning. Third, classroom time can be used to deepen their learning about more difficult concepts or to help students gain a clear understanding of what they should know.

One characteristic of the dental school curriculum that differs from many other majors is that several professors teach one subject. A class is not led by one teacher for a whole semester; rather, the professor changes from one class to the next. Therefore, the amount of material that a teacher wants to cover in a particular period can be very large. It is hard to cram enough learning into the available classroom time. In this situation, it is more effective to distribute learning

materials before class and to conduct a discussion among teachers and students after the class. An online LMS is very useful for this purpose.

Online resources offer an exciting way to reduce individual differences in learning ability by providing students with lessons prior to class or reinforcing learning through online materials after lectures. Online materials can be reviewed several times without time or place constraints. Moodle also has provided a function that analyzes student usage patterns, which can be helpful for understanding student differences. Knowing prior learning patterns helps a lecturer to understand various students' level of understanding and to address their needs effectively in class.

This study aimed to develop an LMS for dental radiology education using Moodle and to evaluate the educational effect by applying it to dental radiographic interpretation practice.

III. Materials and Methods

This study was approved by the Institutional Ethics Review Board of Seoul National University Dental Hospital (IRB No.ERI17005).

1) e-OMFR development

In this study, Moodle, the last stable version 2.3.2 (Moodle Pty Ltd, Perth, Australia) was used because it was the "last stable" version that had been proven to be stable. Installation of Moodle required a web server (in this study, an Apache server was used) with PHP (a web scripting language) and MySQL (a powerful database management system). Moodle, PHP, and MySQL are all open-source and could be easily installed using APM setup (http://www.apmsetup.com), an open-source software package used to set up web servers.

All the procedures for this study were accomplished using a server with the following specifications: for the hardware, Intel (Intel, Santa Clara, CA, USA) ® Core (TM) i7-4770 CPU @3.40 GHz (8 CPUs) and 16.0 GB RAM; for the software, Windows server 2008 R2 Enterprise 64-bit (6.1, build 7600) operating system(OS), MySQL 5.1.33 Database, Apache 2.2 web server, and PHP 5.3.2.

The installation process was as follows. First, the installation files from "standard Moodle package version 2.3.2" were downloaded to the server. The files were renamed to Moodle and decompressed for installation.

Second, a Moodle database folder was created on the server. Future data would be stored in this folder.

Third, "install.php" in the Moodle directory was run. Running this file in a browser

created a "config.php" file in the directory where Moodle software was installed. After the system information was set according to the step (Figs. 1A–E), the installation was complete (Fig. 1F).

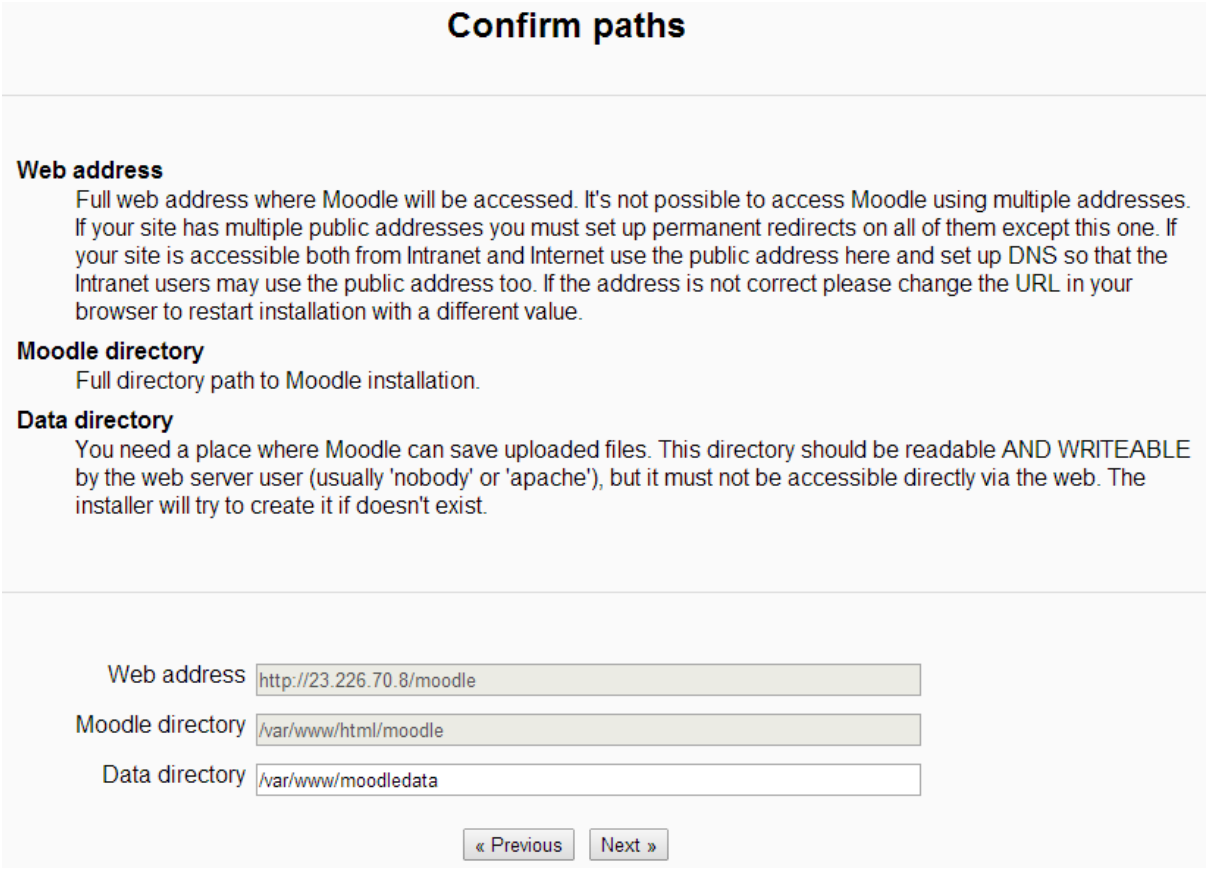


Fig. 1A. Installation path for Moodle shows the web address and Moodle directory set by the installation script by default.

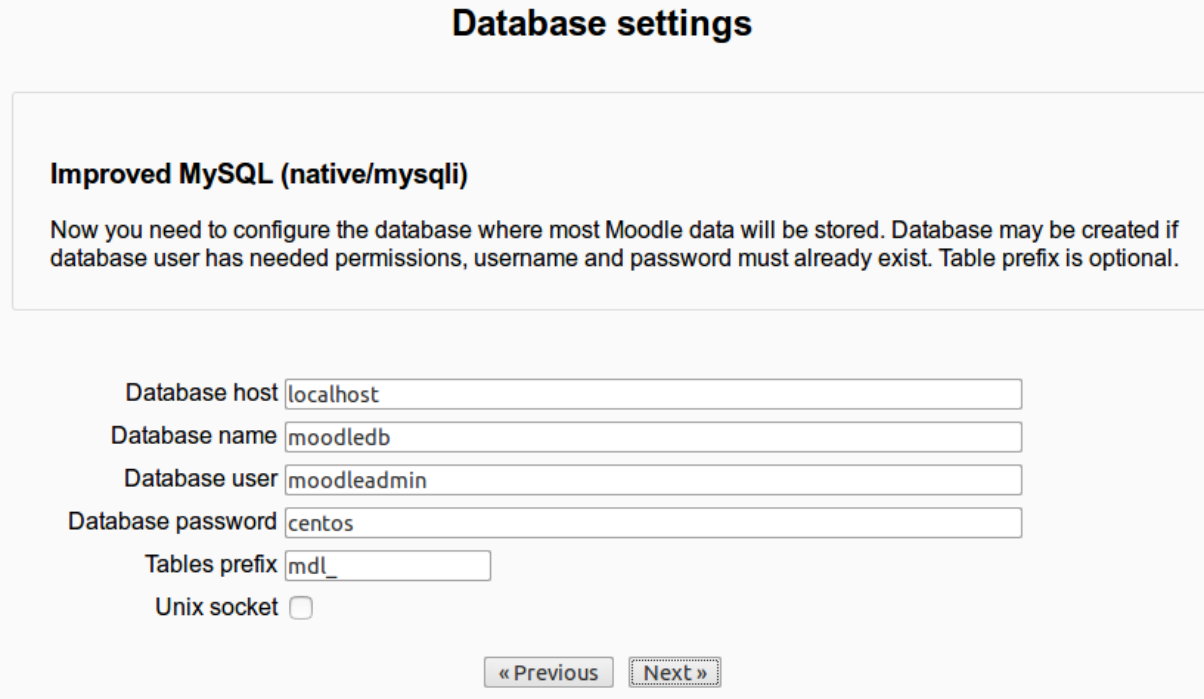
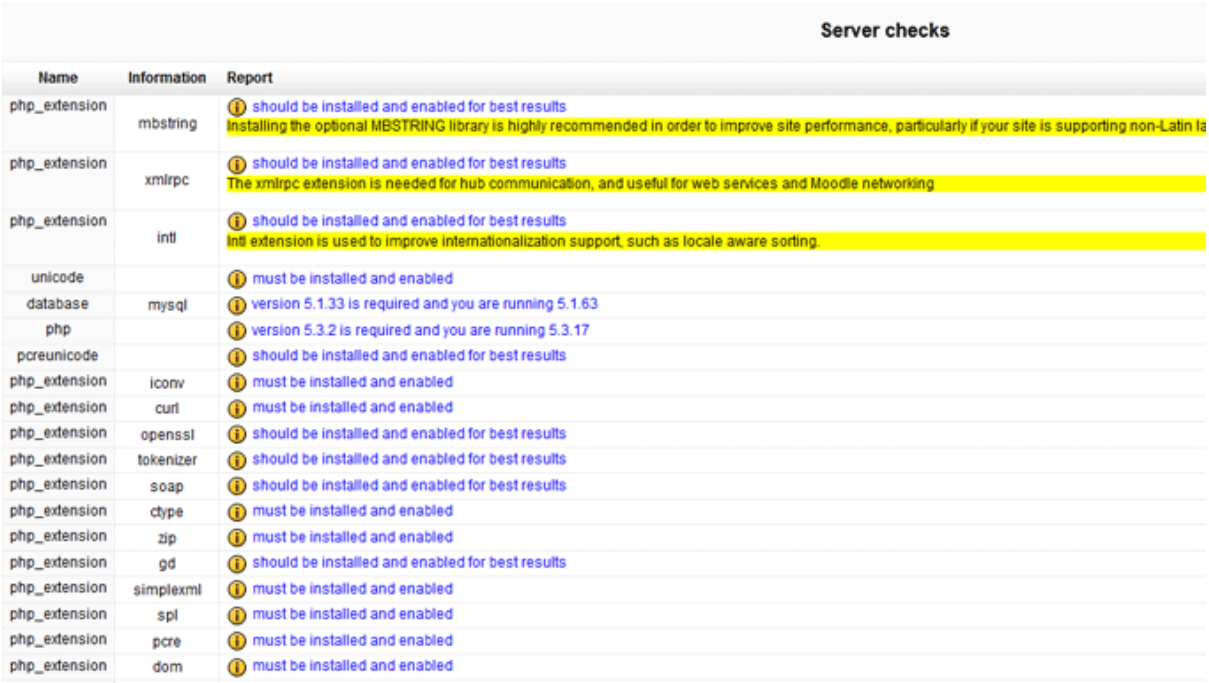


Fig. 1B. Database settings are specified to be used by Moodle. The host server is the address of the computer that will run the database. For the most part, the hostname of the server is localhost. If the database is on another server, the IP address or web address of the server should be entered.



Server checks

Name	Information	Report
php_extension	mbstring	should be installed and enabled for best results Installing the optional MBSTRING library is highly recommended in order to improve site performance, particularly if your site is supporting non-Latin la
php_extension	xmlrpc	should be installed and enabled for best results The xmlrpc extension is needed for hub communication, and useful for web services and Moodle networking
php_extension	intl	should be installed and enabled for best results Intl extension is used to improve internationalization support, such as locale aware sorting.
unicode		must be installed and enabled
database	mysql	version 5.1.33 is required and you are running 5.1.63
php		version 5.3.2 is required and you are running 5.3.17
pcreunicode		should be installed and enabled for best results
php_extension	iconv	must be installed and enabled
php_extension	curl	must be installed and enabled
php_extension	openssl	should be installed and enabled for best results
php_extension	tokenizer	should be installed and enabled for best results
php_extension	soap	should be installed and enabled for best results
php_extension	ctype	must be installed and enabled
php_extension	zip	must be installed and enabled
php_extension	gd	should be installed and enabled for best results
php_extension	simplexml	must be installed and enabled
php_extension	spl	must be installed and enabled
php_extension	pcre	must be installed and enabled
php_extension	dom	must be installed and enabled

Fig. 1C. The server checks process shows that the Moodle system automatically checks for PHP settings that are required to enable Moodle to work during installation.

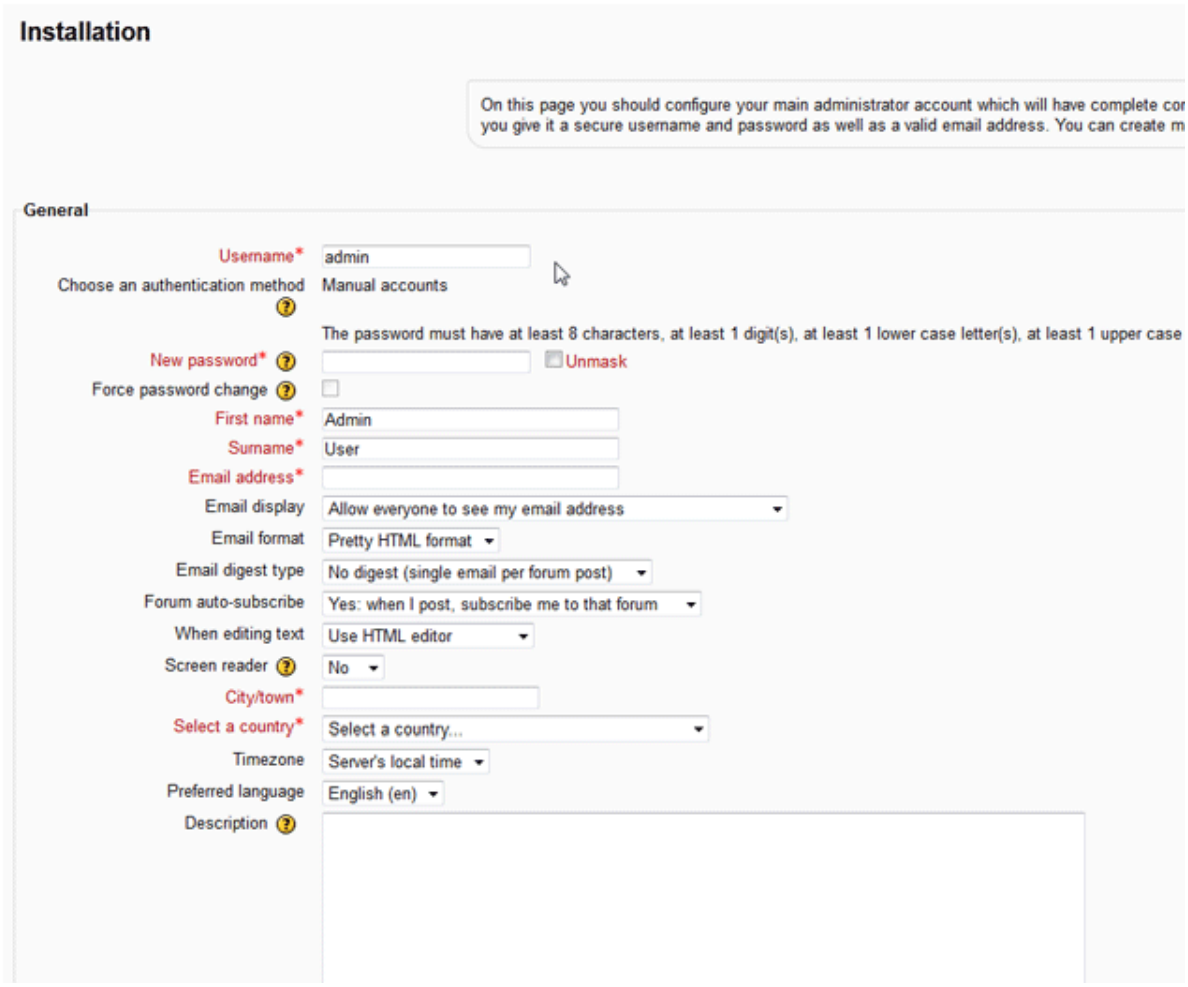


Fig. 1D. The creation process shows that the administrator account with the highest authority is created.

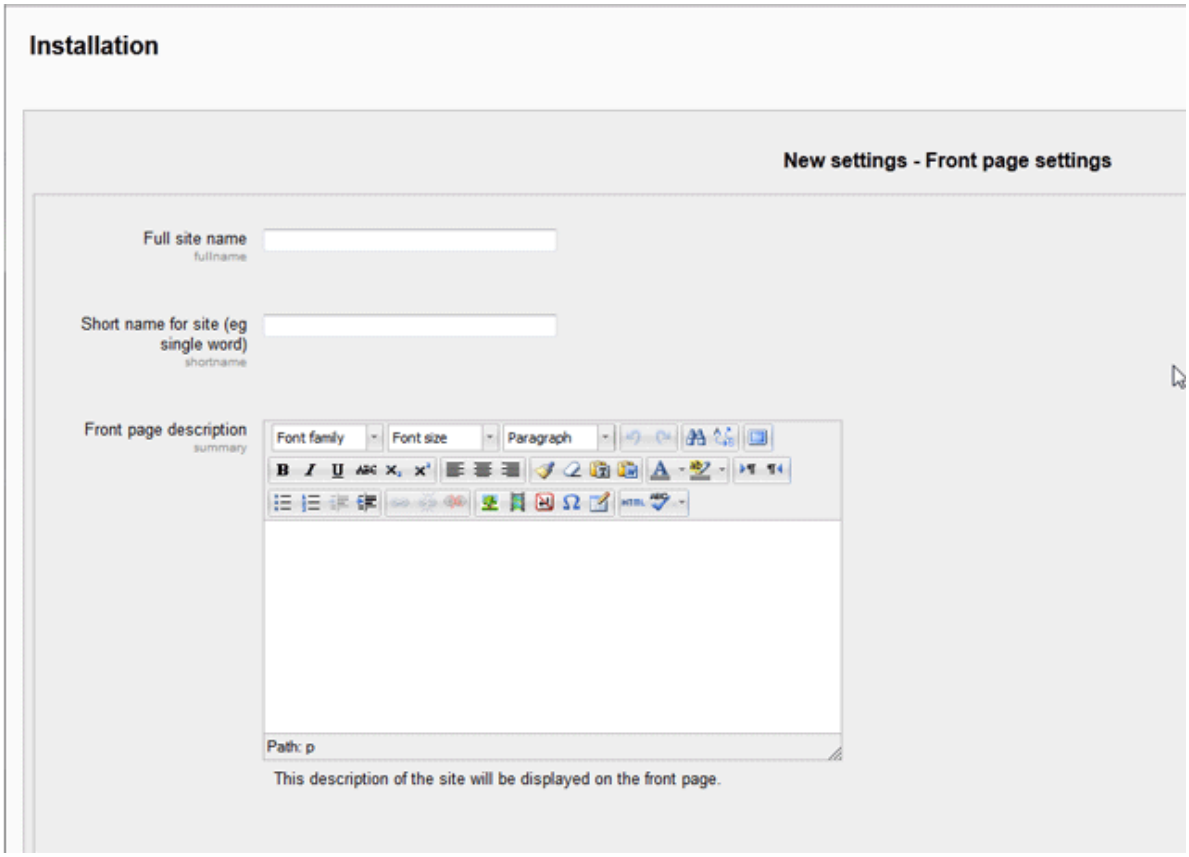


Fig. 1E. The front page settings process, which is not critical because the front page can always be updated via the Moodle administrator backend after installation.

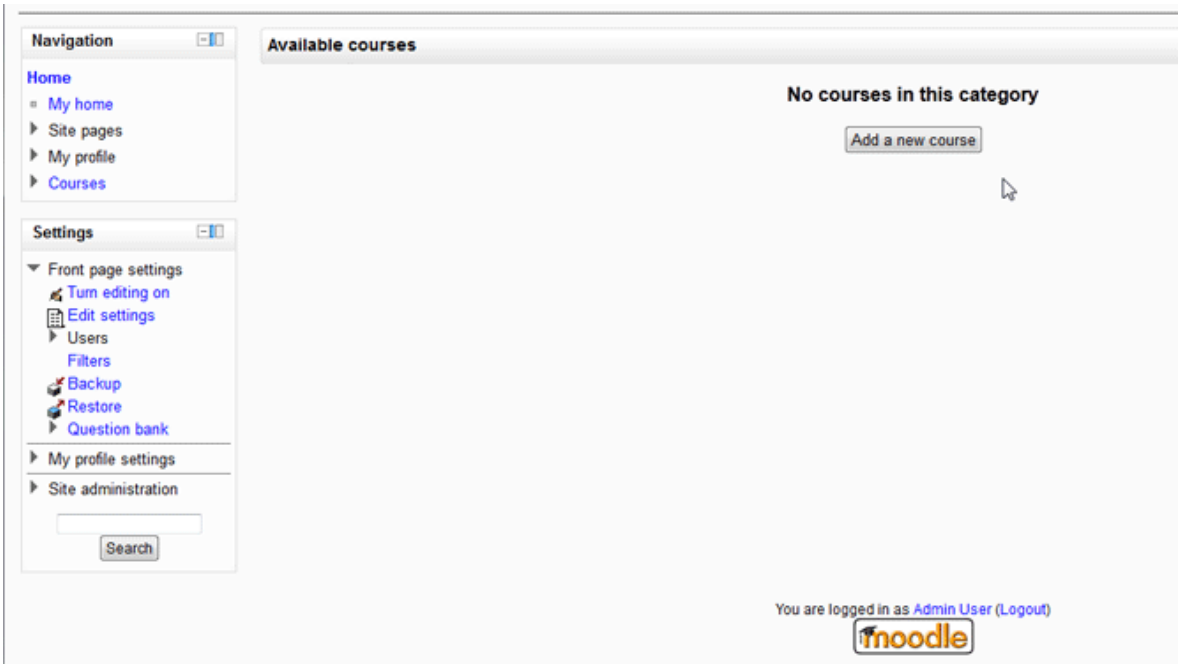


Fig. 1F. Moodle home page.

Fourth, using the customization available in the site administration menu, a new course was created in the "course" menu and was set according to the learning purpose and teaching situation.

The e-OMFR was constructed with four parts: glossary, wiki, forum, and quiz.

First, the Moodle glossary function was used to build a glossary. The glossary provided important concepts and principles and could be used before and during class by uploading videos and photo materials. With this tool, the amount and scope of audiovisual materials made available online greatly exceeded the data available in textbooks.

Second, the wiki function of Moodle allowed students to carry out team tasks online, without meeting together at a particular place and time. This arrangement is especially helpful for the third- and fourth-year students completing their clinical practices. Since participation history was recorded, the instructor could determine

which participants were most active and which students exhibit poor participation.

Third, through the forum function, instructors or learners could ask and answer questions about difficult cases or share a particular case with other learners. The forum could be used for communication during the semester or as material for face-to-face classes. Face-to-face lessons would tend to lack direct communication among learners and between teachers and learners, which could be supplied in greater depth through the forum function.

Fourth, Moodle's quiz function allowed frequent repetitions in diagnosis of dental radiographs. Using Moodle, the instructor could easily construct various types of quizzes such as cloze, essay, matching, multiple choice, random short answer matching, short answer, true/false, and description. Moodle also offered various functions to help learners acquire knowledge effectively. The instructor could specify a period within which to allow quiz attempts, limit the time for finishing a quiz, or allow or disallow multiple attempts. If a quiz was taken several times, the instructor could choose whether to count the highest score, the first result, or the average of the results when evaluating performance. The instructor could also rearrange the questions or choices and can set up the system to give either instant or delayed feedback after the students have answered all the questions.

2) e-OMFR evaluation

Panoramic radiographs confirmed by oral and maxillofacial radiologists were collected from the Department of Oral and Maxillofacial Radiology of Seoul National University Dental Hospital. To protect patients' private information, server installation and radiographic interpretation practice were performed in the hospital.

Third-year students of the School of Dentistry at Seoul National University have

five sessions of dental radiographic interpretation practices in a semester and take a quiz or examination after each practice session. During three weeks of one practice session, students participate in the practice once. The practice session lasts 4 hours, consisting of 3 hours of interpretation practice and one hour of question and answer.

Seoul National University Dental Hospital is using the picture archiving and communication system(PACS), and students are familiar with PACS because they receive dental radiographic interpretation education with PACS.

The conventional practice was as follows. The students first interpret extra-oral radiographs which were taken on the same day at the Department of Oral and Maxillofacial Radiology of Seoul National University Dental Hospital. Students should interpret at least 10 cases. The quantity and quality of the radiographic interpretations were reflected in their assessments. If students had any questions while interpreting, they should write down their questions to ask the instructor during the question and answer time of the practice session. During interpretation practice time, students should make a note of the interpretation. After three hours of interpretation practice, there was a question and answer time for one hour. After the practice session, students should check the revisions made by the instructor and submit the report in the next practice session. The report contained both the original interpretations and the confirmed interpretations. It was the process of reviewing what one has misinterpreted by checking the differences between the interpretations.

In order to evaluate the e-OMFR, the students were divided into two groups. The control group did the conventional interpretation practice for 3 hours in the last practice session. For the experimental group, half of the last practice time (1.5

hours) was replaced with online practice using e-OMFR. Thus, 10% of the total practice time was replaced by online practice using e-OMFR.

The students were selected randomly for the experimental group that received online practice to reduce the bias of the study. Students chose their practice date according to their schedule, which contributed to eliminating any pattern and tendency. The number of students who participated in the practice was 5 to 6 per day. The dates of online practice were randomly selected and the students who had chosen those days were selected as the experimental group.

Of the 79 third-year students, 40 (51%) were males and 39 (49%) were females. Their average age was 29 years. The two groups were demographically similar; specifically, the experimental group comprised 21 males and 21 females, with an average age of 28, whereas the control group comprised 19 males and 18 females, with an average age of 29.

There was no prior notice about online practice. Students' IDs were created in advance and allocated 5 minutes before the start of the practice. The students were briefly informed about e-OMFR for 5 minutes, and then the practice was carried out.

The experimental group was allowed to spend 1.5 hours of the total 15 hours of practice time doing online practice. This group practiced diagnosing dental caries through online quizzes. Students were given more than 100 panoramic radiographs and indicated the FDI (the Federation Dentaire Internationale numbering system) number of teeth with caries on each radiograph within a limited period. The answers did not have to include the site of dental caries. Figure 2 shows a screenshot of an e-OMFR quiz. Students were asked to carry out their diagnosis in a stated order, proceeding from the maxillary right to the maxillary left, mandibular

left, and mandibular right, and enter the FDI numbers of teeth with caries in each portion of the mouth. Students received the correct answers, their scores, and feedback on their answers after completing groups of 30 radiographs. The quiz results were not included in the formal assessment.

Fig. 2. Screenshot of a quiz which asks to indicate the FDI number of teeth with dental caries in each portion of the mouth.

Examination scores

During their clinical education period at the Department of Oral and Maxillofacial Radiology of Seoul National University Dental Hospital, third-year students take four quizzes and one final examination. Each quiz comprises 10 questions that require diagnosis of lesions on intraoral radiographs or panoramic radiographs, which includes dental caries diagnosis. The final examination comprises more than 50 questions. For this study, 10 questions on diagnosing dental caries on panoramic radiographs were added. Each panoramic radiograph included at least one tooth with caries. Table 1 shows how many teeth with caries are included in the panoramic radiographs of the 10 questions.

Table 1. The number of teeth with caries in the panoramic radiographs of the 10 questions

The number of teeth with caries	The number of questions
1	2
2	4
More than 3	4
total	10

The 10 questions were scored according to the scoring criteria (Table 2).

Table 2. Scoring criteria

The number of teeth with caries	Student's answer	Points
1	If one matches	3
	False negative answer	−1
2 ≥	If two or more match	3
	If one matches	2
	False negative answer	−1

The score for these additional 10 questions was not included in the formal assessment. The effectiveness of e-OMFR was evaluated by comparing the final examination scores of the two groups. In addition, previous quiz scores were compared to see if there was any difference between the two groups before the experimental group did the online practice.

The final examination was given in its traditional form. No prior notice was given to the students about the online practice and the added 10 problems in the final examination.

Questionnaire

To survey e-OMFR, a questionnaire was administered to the students after they completed their final examination. The questionnaires comprised two parts. The first part covered demographic characteristics (age, sex, and undergraduate major subject). The second part, which involved subjective assessment of e-OMFR developed in this study, was given only to the experimental group. Students were asked if there was any inconvenience to using e-OMFR and if the quiz difficulty was appropriate. Along with five rating questions, it asked for narrative responses to four open-ended questions related to the students' overall experience with e-OMFR. (see Appendix)

3) Statistical analysis

The mean and standard deviation were calculated for all scores. Student's t-test was conducted to determine whether there were statistically significant differences between the groups. The significance level was set at $p<0.05$. All statistical analyses were performed using SPSS (IBM SPSS Statistics, version 20, IBM, Armonk, NY, USA).

IV. Results

1) e-OMFR development

The process of installing and customizing Moodle was feasible and cost-effective. Using Moodle, an LMS suitable for dental radiographic interpretation practice could be developed

Student Feedback from the Questionnaires

The students in the experimental group were surveyed to obtain their subjective evaluation of e-OMFR. The results are presented in Table 3.

Among the students in this group, 27% answered that the online quizzes were helpful in dental caries interpretation practice and 35.1% were positive about introducing online practice into dental radiographic interpretation practice.

However, 54% of the students answered that they found e-OMFR inconvenient. Those who expressed discomfort with the system gave the following reasons: it was impossible to enlarge the panoramic radiographs; it was difficult to grasp the structure; the resolution was low; it would be better to see the right answer immediately; there was not enough time for reviewing; there were no density and contrast control functions; the user interface was inconvenient; and there was not enough explanation of the answers. When asked whether the online practice had improved their ability to diagnose dental caries, 21.6% responded negatively and 13.5% responded positively.

Table 3. Summary of student responses to five statements provided in the questionnaire, on a five-point Likert scale

	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		
	n	%	n	%	n	%	n	%	n	%	Mean±SD
Statement 1. The system was convenient to use.	0	0	5	13.5	12	32.4	17	45.9	3	8.1	2.51±0.8
Statement 2. The difficulty level of the quizzes was appropriate.	0	0	7	18.9	14	37.8	14	37.8	2	5.4	2.70±0.8
Statement 3. The quizzes were helpful in interpretation practice.	2	5.4	8	21.6	18	48.6	7	18.9	2	5.4	3.03±0.9
Statement 4. My ability to diagnose dental caries improved after the online practice.	1	2.7	4	10.8	24	64.9	7	18.9	1	2.7	2.92±0.7
Statement 5. I recommend including online practice in interpretation practice.	3	8.1	10	27.0	14	37.8	5	13.5	5	13.5	3.02±1.1

Statements were scored using a five-point Likert scale, where 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree.

2) e-OMFR evaluation

Examination scores

No significant difference was detected between the two groups on previous quizzes and on the 50 questions of the final examination excluding dental caries diagnosis on panoramic radiographs (Table 4). The maximum score for each quiz and the final examination was 10.

Table 4. Previous quizzes and final examination scores (maximum score = 10)

Group	N	First quiz	Second quiz	Third quiz	Fourth quiz	Final exam
Control	37	4.71±0.73	5.28±1.87	4.47±2.27	5.66±2.02	4.37±1.25
Experimental	42	4.43±1.00	5.13±2.08	4.87±2.26	5.68±1.65	4.27±1.41
p value		0.156	0.734	0.443	0.963	0.742

Values are mean ± SD.

The students in the experimental group scored higher than the control group on the 10 questions that covered dental caries diagnosis on panoramic radiographs (Table 5). The maximum score was 30.

Table 5. Scores for diagnosis of dental caries on panoramic radiographs (maximum score = 30)

	N	Score	*p* value
Control	37	9.32 ± 7.01	0.003*
Experimental	42	13.76 ± 5.78	

Values are mean ± SD; *indicates significant difference ($p < 0.05$)

V. Discussion

In this study, Moodle was introduced for instructors who aimed for more effective teaching by applying e-learning to dental radiology education. An online LMS design that could supplement offline lectures was proposed. Building a dental radiology LMS using Moodle was feasible at the cost of purchasing a regular personal computer.

Moodle's official site offered various formats and versions. It had "last build" and "last stable" versions, and installing the "last stable" version was recommended. The "last build" means that a bug in the program had been fixed or that the program had been revised to make it the last updated version. Although the "last stable" version did not have the latest functionality, it was a version with proven stability and had all the features that were usually required. Therefore, the "last stable" version was sufficient for developing and running an LMS.

The e-OMFR was established using the web-based Moodle system for e-learning. The advantage of this method was that students could access the system using their own computers at home, averting the need to allocate a large number of computers for student use. As technical issues related to obtaining an Internet connection might occur, this potential limitation should be considered while developing the program.

The most important factor in designing the online learning site was to ensure that it effectively complemented offline learning in accordance with the nature of the subjects.[45] The design could vary depending on the subject. In this instance, current dental radiographic interpretation practice was examined, and what could be complemented in terms of learning efficiency was considered. We discussed

how existing educational problems could be overcome using Moodle functionality.

The LMS, or e-OMFR, introduced in this study did not involve advanced or new technology. The important thing was investigating how to use e-OMFR in the educational field. Dental radiographic interpretation practice needed a more practical approach. In previous studies,[5,16,18,24] online education was a simple substitute for lectures. In contrast, this study designed blended learning to use limited radiographic interpretation practice time efficiently.

The e-OMFR was effective when introduced into the students' curriculum, as shown by the experimental group's superior performance on the exam questions related to their dental radiographic interpretation practice. A series of questions supported sequential and thorough practice in panoramic radiographic interpretation. Reinforcement of learning was possible because of the abundant number of radiographs. Furthermore, students were able to practice dental radiographic interpretation with up-to-date radiographs obtained in real clinics, rather than old radiographs from textbooks.

With the conventional teaching method, individualized education might not be possible. Using e-OMFR, the instructor could measure learners' understanding on the basis of their pre-class quiz results and refer to these results in subsequent lectures.

This study involved quantitative evaluation. Previous studies have evaluated e-learning quantitatively.[5,18,24] However, in those studies, students in the experimental group and students in the control group were at different grade levels, and the differences in skill between the two groups likely biased the outcomes. Moreover, these studies used final examination scores[24] or NBDE (National Board Dental Examination)[5,18] results to compare the achievement of the two groups,

which would bias the outcomes as well. Therefore, the evaluation method in this study was designed to reduce bias. The evaluation was conducted with students from the same grade. The interpretation abilities of the two groups were checked by comparing scores of previous quizzes. Students in both groups could be assumed to be similar on all conditions except the 1.5 hour online practice.

This experimental design could cause ethical issues. Online practice which was expected to have better educational effects would be provided for only some students in the grade. Therefore, a minimal amount of time teaching only specific subjects was allocated. In other words, online practice for 1.5 hour was limited to dental caries diagnosis on panoramic radiographs.

The students' scores in the experimental group were significantly higher in the test on dental caries diagnosis on panoramic radiographs. Although this might be considered to be the result of intensive education on a specific subject, not the effect of online practice, the use of the online education tool for intensive education was very efficient and could not be considered separately. To confirm the homogeneity of the two groups, the results of the previous quizzes and final examination, excluding the 10 questions on dental caries diagnosis on panoramic radiographs, were compared.

To compare the educational effects with minimum bias, the online practice of the experimental group was conducted during the regular interpretation practice time. In practice, however, students would have access to e-OMFR anytime and anywhere, enabling them to learn outside class as well. This flexibility could be a great advantage due to the limited time typically allocated for dental radiographic interpretation practice.

Students' feedback indicated that they found the Moodle site helpful for

improving their radiograph diagnostic skills. However, they complained that there were no image control functions because they were familiar with the picture archiving and communication system (PACS) in the hospital. They answered that immediate feedback every time they completed an online quiz question would be more helpful for their practice. When students were asked whether the online practice had improved their ability to diagnose dental caries, more students responded negatively than positively. It may be that the students themselves lacked confidence about whether their interpretation ability had improved because the absolute time for using e-OMFR was short. It would be necessary to select radiographs with educational value and build a database to maximize the educational effect. For example, if students had been intensively trained with radiographs that trigger false negative interpretation or false positive interpretation, the learning effect would have been greater.

Despite the educational potential of e-learning, the method has been criticized from the viewpoint of that it could not bring about a fundamental change in the actual teaching of classes, and that the existing method of teaching and learning should be strengthened instead. In addition, research on e-learning has been criticized for focusing solely on the output of the change rather than on the instructional process, thus failing to solve problems that arose during the actual course. Alternatively, some have argued that e-learning should be accepted as a new educational alternative consistent with current trends. This progressive view might encounter psychological resistance and conservative voices advocating for the continuation of lecture-oriented education. Therefore, it would be necessary to prepare instructional plans and guidelines to assist teachers in appropriately restructuring face-to-face learning.

This study demonstrated the feasibility and effectiveness of online dental

radiographic interpretation practice using Moodle. Although e-OMFR required improvement, it still showed a beneficial educational effect. Overcoming the current problems would result in a more user-friendly system.

To support effective online learning, it was important to develop high-quality educational content. The cooperation of dental schools could reduce the burden of this task. Technology is not the core of education; rather, it supports education. Therefore, curriculum revisions should come first and the use of technology could then be considered in accordance with the improved curriculum.

More follow-up studies are needed. For example, it is important to consider how to encourage students who are not accustomed to online learning or motivated to engage with the LMS. Further studies objectively evaluating knowledge acquisition and retention are required. Although this study approached the topic from the viewpoint of blended learning, it would be possible to design another study method from the viewpoint of flipped learning. For example, by having students take the online quizzes before the radiographic interpretation practice, students could be divided into groups with high false negative interpretation rate and high false positive interpretation rate, and a study could train the two groups separately and compare the results. The introduction of online education systems into dental radiology education would have a major impact on the education process and could be extended in various ways, such as to encompass continuing education for dentists.[46-48]

VI. Conclusion

This study demonstrated that the development of an LMS and its adaptation to dental radiographic interpretation practice were feasible and cost-effective. The incorporation of e-OMFR within current teaching approaches was shown to improve student performance. The e-OMFR could be practically applied to radiographic interpretation practice if the functionality was improved. It could be used in various ways according to the nature of the subject, the teaching situation and the learning objectives. It could also be extended to continuing education for dentists.

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요약(국문초록)

영상치의학 판독 교육을 위한 학습 관리 시스템의 개발 및 평가

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(지도교수 허민석)

1. 목 적

본 연구의 목적은 Modular Object-Oriented Dynamic Learning Environment (Moodle)을 이용하여 영상치의학 판독 교육을 위한 학습관리시스템(Learning Management System, LMS)을 개발하고 이에 대한 교육적 효과를 평가하는 것이다.

2. 재료 및 방법

Moodle은 오픈 소스 학습관리시스템(OSS-LMS) 중에서 기능과 안정성이 검증된 소프트웨어이다. 본 연구를 위해서 Moodle을 서버컴퓨터에 설치하고 판독교육에 적합하게 재구성하여 e-OMFR를 개발하였다. e-OMFR의 기능 중에서 퀴즈 기능을 사용하여 판독 실습을 위한 강의를 구성하였다. 서울대학교 치의학전문대학원 3학년

학생들의 2학기 판독 실습 시간에 e-OMFR을 활용하도록 하였다. e-OMFR의 교육적 효과를 평가하기 위해 학생들을 실험군과 대조군으로 나누어 대조군은 판독 실습을 기존과 같이 진행하도록 하였고 실험군은 총 15 시간의 실습 시간 중 1.5시간을 온라인 판독 실습을 진행하도록 하였다. 실험군의 학생들은 e-OMFR을 이용하여 100장 이상의 파노라마방사선영상에서 치아우식증을 판독하는 온라인 학습을 시행하였다. 최종 시험에 파노라마방사선영상에서 치아우식증을 판독하는 문제 10개 문항이 포함되었고 두 그룹의 성적을 비교하여 교육 효과를 평가하였다. 또한, 온라인 교육에 참여한 학생들을 대상으로 설문조사를 실시하여 e-OMFR에 대한 만족도를 평가하였다.

3. 결 과

Moodle은 오픈 소스 패키지 형태로 되어 있어 적은 비용으로 학습 관리 시스템을 제작할 수 있었다. 퀴즈를 반복 시행하여 파노라마방사선영상을 철저히 판독하도록 학생들을 훈련시킬 수 있었다. e-OMFR을 이용하여 훈련한 실험군 학생들은 최종 평가에서 파노라마방사선영상을 이용하여 치아우식증을 판독하는 10개 문항에서 더 높은 성적을 받았다($p<0.05$). 반면, 최종 시험 중 치아우식증 문항을 제외한 50개 문항에 대한 점수와 이전에 주기적으로 시행한 시험의 점수에 대해서는 두 그룹간에 통계적으로 유의한 차이가 없었다. 실험군 학생의 54%가 e-OMFR이 편리하지 않다고 답하였으며 불편함의 이유로 영상의 확대나 조절이 안 되는 것을 지적하였다. 그럼에도 불구하고, 27%의 학생이 e-OMFR이 치아우식증 판독 훈련에 도움이 되었다고 평가하였다.

4. 결 론

본 연구에서는 Moodle 소프트웨어를 이용하여 영상치의학 학습 관리 시스템인 e-OMFR을 개발할 수 있었다. e-OMFR은 3학년 학생들의 판독 실습에 이용할 수 있었으며 이를 이용한 학생들의 학습 성과가 향상되었다. 교육적 효과와 효율성을 증진시키기 위하여 치과대학에서 e-learning을 도입하는 것이 바람직하며 지적한 문제점을 보완한다면 e-OMFR을 실제 교육에 적용하는 것도 가능할 것이다.

주요어 : 영상치의학, 교육, 학습 관리 시스템

학 번 : 2013-30653

부록(설문지)

파트1. 응답자 특성

※ 다음은 귀하의 일반적 인구통계 특성을 알아보기 위한 질문입니다. 각 항목을 읽어보시고, 해당 보기의 빈 칸에 표시해 주십시오

1. 귀하의 성별은? 남자 ( ) 여자 ( )
2. 출생년도는? ( )
3. 현재 학년은? 1학년 ( ) 2학년 ( ) 3학년 ( ) 4학년 ( )
4. 학부 전공은 무엇입니까?
   자연과학계열 ( ) 이공계열 ( ) 상경계열 ( ) 인문계열 ( ) 사회과학계열( )
   기타 ( )

파트2. 온라인 판독 훈련에 대한 설문

1. 귀하의 학번은 ( )
2. 홈페이지를 사용하는데 불편함은 없었다.
   ① 전혀 아니다. ② 아니다 ③ 보통이다 ④ 그렇다 ⑤ 매우 그렇다

   5-1. ①, ② 로 답한 경우, 어떤 불편함이 있었는지 기술해 주세요
   ( )
3. 홈페이지에 게시된 퀴즈의 난이도는 적절했다.
   ① 전혀 아니다. ② 아니다 ③ 보통이다 ④ 그렇다 ⑤ 매우 그렇다
4. 홈페이지에 게시된 퀴즈는 치아우식증 판독 훈련에 도움이 되었다.
   ① 전혀 아니다. ② 아니다 ③ 보통이다 ④ 그렇다 ⑤ 매우 그렇다
5. 홈페이지에 게시된 퀴즈를 푼 후 치아우식증을 판별하는 능력이 향상되었다.
   ① 전혀 아니다. ② 아니다 ③ 보통이다 ④ 그렇다 ⑤ 매우 그렇다
6. 기존 원내생 교육과정에 온라인 교육이 포함되기를 희망한다.
   ① 전혀 아니다. ② 아니다 ③ 보통이다 ④ 그렇다 ⑤ 매우 그렇다
7. 원내생 교육과정 외 시간에 온라인 교육을 활용할 의향이 있다.

① 전혀 아니다. ② 아니다 ③ 보통이다 ④ 그렇다 ⑤ 매우 그렇다

8. 그 외 온라인 교육 도입 관련 의견이 있으시면 자유롭게 기술해 주세요.

( )

Appendix (Questionnaire)

Part 1. Demographic profile

1. Gender: Male/Female
2. Age: ( )
3. Year: 1st ( ) 2nd ( ) 3rd ( ) 4th ( )
4. Undergraduate course: ( )

Part 2. Survey for students who used the e-OMFR during radiographic interpretation practice

1. Your student number ( )
2. e-OMFR was convenient to use
   ① Strongly agree ② Agree ③ Neutral ④ Disagree ⑤ Strongly disagree

   5-1. If you answered ④ or ⑤, please describe what the inconvenience was
   ( )
3. The difficulty level of the quizzes was appropriate.
   ① Strongly disagree ② Disagree ③ Neutral ④ Agree ⑤ Strongly agree
4. The quizzes were helpful in radiographic interpretation practice.
   ① Strongly disagree ② Disagree ③ Neutral ④ Agree ⑤ Strongly agree
5. My ability to diagnose dental caries improved after the online practice.
   ① Strongly disagree ② Disagree ③ Neutral ④ Agree ⑤ Strongly agree
6. I recommend including online practice in radiographic interpretation practice.
   ① Strongly disagree ② Disagree ③ Neutral ④ Agree ⑤ Strongly agree
7. I would like to use online practice for individual assignment time.
   ① Strongly disagree ② Disagree ③ Neutral ④ Agree ⑤ Strongly agree
8. Please describe if you have any opinions on the introduction of online practice.
   ( )